REVIEW OF LITERATURE
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Coir retting and its importance

Coir is a unique natural fiber used in diverse applications. Coir retting is one of the major and small scale industry found in the southern part of India. This industry provides employment to a large no of people especially women flock, who find this work as a source of their principle income (Vinodhini et al., 2006). Retting is the basic process serving as the backbone of coir industry. It is a common experience that fibers detached from the coconut skin are quite hard to break by simple tension, hence by pulling from both sides. Excellent properties of resistance to wear and easy availability in countries, such as India, where coconut palms are widespread, have allowed coir to be employed for a variety of uses, e.g., for manufacturing toys, bags and carpets. More recently, coir has also found additional applications, which appear to be gradually replacing the traditional ones and possibly create an alternative market for coir and coconut palms by-products (Moir 2002). For example, coir is recently used to manufacture containment nets aimed at protecting soil from erosion, thereby replacing polyester nets, with the added advantage that coir nets will not need to be removed eventually, since they act as an active support to plants growth (Rao et al., 2000). Another interesting possibility is the replacement of wooden boards with coconut husk boards (Van Dam et al., 2004).
The latter example is particularly suggestive of a field of application, which is becoming increasingly important in the last decade, and which can present both environmental and economic importance, in particular for the developing countries: the use of vegetal fibers to obtain materials capable of replacing plastics. This replacement is likely to be largely supported worldwide in the near future, in that it presents substantial environmental advantages, including the fact that a wider use of plant fibers in materials offers a better end-of-life scenario for the components (Czigany 2004).

Plant fibers production issue is crucial for both environment and Third World development. Coir, which has been used for at least 4000 years, may have the potential to become an environmentally friendly material of large use in the world. Natural rubber, recently coupled to coir in a number of industrial products (e.g., rubberized coir, which consists of natural latex and coir hair molded into cushions and pads for the automotive industry), and this adds to the possibility of developing a local industry on coir based plastic replacement products (Chand 1995).

In the particular case of the automotive industry, restrictions on scrapped car disposal are gradually coming into force, such as the directive adopted by the European Commission in September 2000 which impose a larger use-of biodegradable materials in car manufacture (European Commission 2000). However, the need to obtain automotive components with a number of properties, including e.g., biodegradability, absence of odor, structural resistance and easy finishing, has
brought automotive manufacturers to be rather attracted by products obtained combining two or more natural fibers (often referred to as hybrids) (Snijder et al., 2000).

**Coir retting physic co-chemical variation**

The retting of coconut husks in backwaters is bought about by the pectinolytic activity of micro organisms especially bacteria fungi and yeasts degrading the fiber binding materials of the husk and liberating large quantities of organic matter and chemicals in to the environment including pectin pentosan, tannins, polyphenolys, etc. Consequently hydrogen sulfide, phosphate and nitrate contents increase while dissolved oxygen and community diversity of plankton decrease in the ambient waters during the retting process (Remani et al., 1989).

The present study is to evaluate pollution due to coir retting activity and its influence on quality of water and estuarine flora and fauna organic matter show enrichment in the retting ground sediments.

Bacterial contribution to total organics was consistently higher at the each stage (Remani et al., 1981) environmental pollution due to retting of coconut husk and preliminary studies on closed system retting has been studied by Abbassi et al.,(1982). The retting is the basic process involved in the manufacture of the coir. It is a biological process which involves the pectinolytic activity of the micro organism especially bacteria and fungi present in the retting ground that liberates large quantities organic c substances into the medium (Jayasanker ,1985)
Retting of coconut husk in most of the wet land led to acidic pH condition with anoxia resulting in the production of high amounts of sulphide coupled with high carbon dioxide value leading to drastic reduction in the incidents in the abundant of plankton, benthic fauna, and fishery resources the majority of these backwaters are highly stretched especially during the pre monsoon period when the retting activity is at the peak (Bijoy nanthan, 2004). Retting is the basic process serving as the back bone of the coir industry in Kerala. The shallow fringes of kayals (estuaries) and channels drawn from them are the traditional sites for the retting of coconut husk.

Retting is brought about by the pectinolytic activity of micro organisms especially bacteria, fungi, east degrading the fiber binding materials of the husk and liberating large quantities of organic matter and chemicals into the environment. Retting of coconut husk has thus anoxic conditions along with the increase in hydrogen sulphide with a sharp depletion in the biotic communities (Jayasankar and Menon, 1961 Bijoy nanthan et al., 1995,).

The retting source in estuaries are thus exposed to prolonged periods of anoxic conditions resulting from total oxygen depletion and remarkably high concentrations of hydrogen-sulphide, thus causing extensive damage to the living aquatic resources in the region. The paper deals with the indicator organisms specific to pollution from retting of coconut husk in the kayals of kerala (Bijoy nanthan et al., 1995)
High values of hydrogen sulphide, ammonia, BOD, are associated with anoxic condition and low community diversity of plankton, bentic fauna, fish, shellfish, wood boring and fouling organisms where the outstanding future of the retting source (Nanthan et al., 1999).

The impact of coconut husk retting on the water quality of Edava nadayara back water has been studied. The water quality has been assessed by measuring various parameters. The significant feature associated with retting is the complete depletion of the oxygen in the retting source in the H2S BOD, COD where significantly higher than non-retting zone. The high content of NO-N during monsoon was contributed by land drainage and high values of pO2/P during the monsoon possibly caused by regeneration from sediment surface (Mathukumar et al., 1996).

Coconut husk retting, a wide spread activity causing organic pollution of the wet lands of Kerala results in release of large quantities of organic substances, like pectin, pentosan, fat, and tanning are liberated in to the water by the activity of fungi and bacteria. The decomposition of the pectin results in the production of hydrogen and sulphide – the basis of nauseating smell in and around the retting zones. High organic content (6 to 13%) high BOD (5137mg/l), low oxygen (0.05ml/l) and high sulphide (4.97mg/l) characteristic of retting zones are found to be devastating for the bottom fauna (Akhila Rajan et al., 2005)

Oxidation of organic matter liberated hydrogen sulphide, adversely affecting the fishery wealth of the area the nature, significance and consequences
of this man made sulphide system where examined in detain its effect on the fishery of the areas was discussed. Fluctuation in the abundance of crustaceans has a direct bearing on fisheries. The Edava nadayara paravur backwater system with the exception of the retting areas supports a rich fishery. Seasonal variations in the crustacean plankton population with reference to the non retting areas were also notice (Abdul Aziz et al., 1982).

The existence of the sulphide system in the retting zone and the seasonal variation in abundance with the non retting area are discussed in detail (Remani et al., 1981). Effects of monsoon were found significant organic carbon and organic matter showed enrichment in the retting ground sediments. Annual average of bacterial biomass was higher in the non retting yard (25.7mg/g) as against (22.8mg/g) in the retting yard. Ecology of the Akathumuri, Anjengo and Kadinamkulam lake and its physiochemical conditions were studied by Balakrishnan nair (1983). Meiofauna of Edava Nadayara backwater system, south west cost of India was studied, ecology and distribution of bendic macrophana in the Asta Moodi estuary of Kerala were attempted by (Balakrishnan nair et al., 1984). Pollution in Cochin backwaters due to coconut husk retting with special reference to benthos was studied (Remini 1989).

Ecology of Vaduthala retting yards in cochin backwaters and its effect on water quality, sediments and estuary communities, especially local fisheries were reported (Ramini et al., 1980). Studies on the sediments of the retting yards with reference to nutrient contents in Kochin back waters were attempted (Ramini et
Indicator organisms among bentic communities which dominated maintaining high population densities in retting yards of cochin backwaters were studied (Ramini et al., 1983). Ramini and Nirmala (1989) classified the retting yards based on hydrology area and intensity of retting activities. The process of retting is found to cause pollution problems in the river mouths and back waters detailed systematic studies were carried out in Kadalundi retting yards and adverse effects of pollution are well marked on local fishery of these areas. Assessment of pollution due to retting of coconut husk and development of alternative Retting Technology was carried out by Remani and Nirmala, (1989) (CWRDM Report). Experiments on the development of alternative retting technology reveals that retting can be practiced in fresh water. The periodicity of retting is prolonged in closed system in anaerobic conditions. Flushing of ret liquor reduces the periodicity of retting without affecting the quality of fiber. Impact of retting industry on the fauna and flora of the backwater system was studied by Remani and Nirmala, (1990). Correlative assessment of benthic communications in the retting yards based on the taxa and ranges of dissolved oxygen (DO) content was carried out by Remani and Nirmala, (1989). The high population density and species richness which are the structural parameters of the benthic community suggests a relationship between community composition and dissolved oxygen regime.
Associated bacteria in Coir retting ponds

A systematic study on the nature and characteristic of the organism bringing about retting of coconut husks and the biochemical transformations involved in the process was carried out under the project study at the Indian Institute of Science, Bangalore. The study of the Project on the microbiological aspects revealed that many aerobic species of bacteria belonging to the genera *Pseudomonas, Escherichia, Micrococcus, Bacillus, Paracolobactrium, Alcaligenes, Archromobacter* and *Aerobacter* and yeast species such as *Saccharomyces fructeum, Debaronyces hansenii, D.nicotinae* and *Rhodotorula flavour*, are intimately involved in the retting process. Most of the organisms and *Pseudomonas* have the ability to attack phenol and catechol. *Micrococcus crytococcus* and other species are capable of liberating pectinolytic enzymes as poly galacturaonase, Pectin trans- eliminase and pectin esterase. (The Indian Institute of Science, Bangalore, 1979).

As part of an environmental abatement programme, through the application of bioremediation in the retting zones of Kerala, a microbiological survey was conducted in the Kadinamkulam kayal, a major retting zone in Kerala. Some selected physico-chemical parameters were also analyzed to assess the water quality in the context of retting activity. Comparatively low dissolved oxygen content coupled with high hydrogen sulphide observed. Salinary distribution is of the mixohaline nature. *Pseudomonas sp., E.coli* and other coliform groups were found in the area. Of these the most dominant was *Pseudomonas sp.* and hence its
nature and plasmid profile were also studied. The study indicates an environmental degradation in the area, and the possibility of hotspots of pollution in the backwater biotopes in the state (Paulmurugan et al., 1999).

Species of Pseudomonas, Micrococcus, Escherichia, Shigella, Salmonella, Klebsiella and Enterobacter were the major groups of microbes inhabiting the retting area. Even though, there are chances of introducing large number of coliform bacteria into the inland water bodies through large drainage. During the present investigation the most dominant species found was that of Pseudomonas (Thomas et al., 2003). Vibrio was also spotted in sample. Anaerobic condition conjoined with the production of hydrogen sulphide is a general phenomenon noticed in the retting area may be lethal to this community (Venkedeswaran et al., 1993).

The dominant Pseudomonas sp inhibiting the retting area could inhibit the growth of other organism in the region. The Pseudomonas sp, at the long course of time might have got acclimatized and, hence the physic-chemical nature might be highly suitable for its succession in the environment. In many aquatic biotopes as a whole, the combined activity of bacterial and other microorganisms, tend to create environmental conditions suitable for the growth of its living resources. But on certain occasions due to anthropogenic activities like coconut husk retting, the activity act as a limiting factor by changing the equilibrium of the P
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Physico-Chemical characteristics of the medium

(Eaton et al., 1995)

**Bacterial biodegradation**

Bioremediation is a treatment process that uses naturally occurring microorganisms (yeast, fungi, or bacteria) to break down, or degrade, hazardous substances into less toxic or nontoxic substances. Microorganisms, just like humans, eat and digest organic substances for nutrients and energy. In chemical terms, “organic” compounds are those that contain carbon and hydrogen atoms. Certain microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans. The microorganisms break down the organic contaminants into harmless products mainly carbon dioxide and water. Once the contaminants are degraded, the microorganism population is reduced because they have used their entire food source. Dead microorganisms or small populations in the absence of food pose no contamination risk.
Microorganisms must be active and healthy in order for bioremediation to take place. Bioremediation technologies assist microorganisms' growth and increase microbial populations by creating optimum environmental conditions for them to detoxify the maximum amount of contaminants. The specific bioremediation technology used is determined by several factors, for instance, the type of microorganisms present, the site conditions, and the quantity and toxicity of contaminant chemicals. Different microorganisms degrade different types of compounds and survive under different conditions.

Indigenous microorganisms are those microorganisms that are found already living at a given site. To stimulate the growth of these indigenous microorganisms, the proper soil temperature, oxygen, and nutrient content may need to be provided. If the biological activity needed to degrade a particular contaminant is not present in the soil at the site, microorganisms from other locations, whose effectiveness has been tested, can be added to the contaminated soil. These are called exogenous microorganisms. The soil conditions at the new site may need to be adjusted to ensure that the exogenous microorganisms will thrive.

Bioremediation can take place under aerobic and anaerobic conditions. In aerobic conditions, microorganisms use available atmospheric oxygen in order to function. With sufficient oxygen, microorganisms will convert many organic contaminants to carbon dioxide and water. Anaerobic conditions support biological activity in which no oxygen is present so the microorganisms break
down chemical compounds in the soil to release the energy they need. Sometimes, during aerobic and anaerobic processes of breaking down the original contaminants, intermediate products that are less, equally, or more toxic than the original contaminants are created.

Bioremediation can be used as a cleanup method for contaminated soil and water. Bioremediation applications fall into two broad categories: in situ or ex situ. In situ bioremediation treats the contaminated soil or groundwater in the location in which it was found. Ex situ bioremediation processes require excavation of contaminated soil or pumping of groundwater before they can be treated.

In situ techniques do not require excavation of the contaminated soils so may be less expensive, create less dust, and cause less release of contaminants than ex-situ techniques. Also, it is possible to treat a large volume of soil at once. In situ techniques, however, may be slower than ex-situ techniques, may be difficult to manage, and are most effective at sites with permeable soil.

The goal of aerobic in situ bioremediation is to supply oxygen and nutrients to the microorganisms in the soil. Aerobic in situ techniques can vary in the way they supply oxygen to the organisms that degrade the contaminants. Two such methods are bioventing and injection of hydrogen peroxide. Oxygen can be provided by pumping air into the soil above the water table (bioventing) or by delivering the oxygen in liquid form as hydrogen peroxide. In-situ bioremediation may not work well in clays or in highly layered subsurface environments because oxygen cannot be evenly distributed throughout the treatment area. In situ
remediation often requires years to reach cleanup goals, depending mainly on how biodegradable specific contaminants are. Less time may be required with easily degraded contaminants.

*Ex situ* techniques can be faster, easier to control, and used to treat a wider range of contaminants and soil types than *in situ* techniques. However, they require excavation and treatment of the contaminated soil before and, sometimes, after the actual bioremediation step. *Ex situ* techniques include slurry-phase bioremediation and solid phase bioremediation. *Staphylococcus, Bacillus, Pseudomonas, Citrobacteia, Klebsilla, and Rhodococcus* are organisms that are commonly used in bioremediation mechanisms (Connor *et al*; 1994, 1996). These mechanisms include bioaugmentation, in which microbes and nutrients are added to the contaminated site, and biostimulation, in which nutrients and enzymes are added to supplement the intrinsic microbes of the site (Connor *et al*; 1994, 1996).

Most bioremediation systems are run under aerobic conditions, but running a system under anaerobic conditions (Colberg *et al*., 1995) may permit microbial organisms to degrade otherwise recalcitrant molecules. To have a physiological or toxic effect, most metal ions have to enter the microbial cell. Many divalent metal cat ions (eg. Mn$^{2+}$, Fe$^{2+}$, Co$^{2+}$, Ni$^{2+}$, Cu$^{2+}$ and Zn$^{2+}$) are structurally very similar. Also the structure of oxy anions such as chromate resembles that of sulfate, and the same is true for arsenate and phosphate. Thus to be able to differentiate between structurally very similar metal ions, the microbial uptake systems have to be tightly regulated. Usually, microorganisms have solved this problem by using
two types of uptake systems for metal ions. One is fast, unspecific, and driven by
the chemiosmotic gradient across the cytoplasmic membrane of bacteria. Since
this mechanism is used by a variety of substrates, it is constitutively expressed
(Nies, 1999). The Second type of uptake systems has high substrate specificity, is
often uses ATP hydrolysis as the energy source and is only produced by the cell in
times of need, starvation or a special metabolic or a special metabolic situation
(Nies and Silver, 1995).

Tannins are water-soluble polyphenolic secondary metabolite of higher
plants which are either galloyl esers or their derivatives (Khanbabae and Ree,
2001). They are the fourth most abundant plant constituents following cellulose,
hemicellulose and lignins; and together with the latter are the most abundant and
widely distributed phenolic polymers of higher plants (Brooker et al., 1999;
Mingshu et al., 2006). Hydrolysable and condensed tannins are the two major
classes of tannins. These compounds have a range of effects on various organisms-
from toxic effects on animals to growth inhibition of microorganisms. Some
microbes are, however, resistant to tannins, and have developed various
mechanisms. And pathways for tannin degradation in their natural milieu. The
microbial degradation of condensed tannins is, however, less than hydrolysable
tannins in both aerobic and anaerobic environments. A number of microbes have
also been isolated from the gastrointestinal tract of animals, which have the ability
to break tannin-protein complexes and degrade tannins, especially hydrolysable
tannins. Tannase, a key enzyme in the degradation of hydrolysable tannins, is
present in a diverse group of microorganisms, including rumen bacteria. This
enzyme is being increasingly used in a number of processes. Presently, there is a need for increased understanding of the biodegradation of condensed tannins, particularly in ruminants.

A tannin-degrading strain of *Bacillus sp* AB1 was isolated from a garden soil by enrichment. This organism was able to utilize 1% (w/v) tannic acid-a gallotannin at 30°C and pH below 4.5 in a defined mineral medium where the acid was the sole source of carbon and energy under 96h. Growth resulted in increase on OD concomitant with gradual decrease in pH of the culture medium. Analysis of the culture fluid by paper chromatography revealed glucose and gallic acid as a major metabolites was recovered after 96h of incubation. The degradation potential of this isolate could be exploited for the production of tannase, improvement of livestock production an also detoxification of tannery effluents at extreme acidic conditions (Ilori *et al*., 2007).

The higher concentration of phosphate noticed especially during monsoon and pre monsoon season are probably associated with bottom turbulence and tidal influence (Padamakumar *et al*., 2002). Microorganisms play an important role for transformation of phosphorous in water and sediments and the phosphate ions are reported to be strongly absorbed by sediments with a high content of silt and clay (Seshadri *et al*., 2002). The solubilization of phosphorous compounds may also be brought about by acids and enzymes of microbial origin (Alexander, 1961; Skujin 1968).
Nitrogen and Phosphorous are usually identified as the limiting factors for biodegradation. This study only focused on the role of nitrogen source in biodegradation of petroleum compounds. Nitrogen compounds were added in the forms of ammonium salts and urea. Ammonium salts, such as ammonium chloride (NH₄Cl) and ammonium nitrate (NH₄NO₃), rapidly release ammonium after application. Ammonium is in a reduced state, which makes it energetically favorable for amino acid formation and other metabolisms. Since large amounts of ammonium were observed increasing biodegradation rates.

Ammonia (NH₃) is the most reduced form of reactive nitrogen. It is also the most abundant alkaline constituent in the atmosphere. In the past 50 years, emissions and the subsequent deposition of NH₃ have increased significantly in parallel with the development of intensive agricultural management and increased livestock numbers (Sutton et al., 1993). It is also the most abundant alkaline constituent in the atmosphere. Once released into the atmosphere, NH₃ has a relatively short residence time of about 1 to 5 d. When airborne, it is either readily converted to aerosol or it is subjected to dry or wet deposition processes. Ammonia is reactive with a variety of acidic atmospheric species, including nitric acid (HNO₃), hydrochloric acid (HCl), and sulphuric acid (H₂SO₄) which result in the formation of ammonium aerosols, i.e., fine particulate matter (aerodynamic diameter < 2.5 μm) due to the extended lifetime of these aeroceils (about 1 to 15 d) nitrogen may be transported to previously pristine regions for from the pollutant sources. Assuming an atmospheric residence time of 6 d and a wind
velocity of 5 m s\(^{-1}\) estimate that ammonium aerosols might travel as far as 2500 km; however, dry and wet deposition may reduce this transport significantly.

Both ammonia and subsequently derived ammonium (NH\(_4^+\)) may be removed from the atmosphere through the wet and dry deposition. Dry deposition occurs by diffusion of NH\(_3\) in the atmospheric boundary layer and the surface layer; wet deposition occurs by below cloud scavenging (washout) and rainout (in-cloud processes). Fine particulate (NH\(_4^+\)) is efficiently removed from the atmosphere mainly through wet deposition. Overall, wet deposition is more important in regions with low NH\(_3\) emissions. Conversely, dry deposition is more important in regions in high NH emissions.